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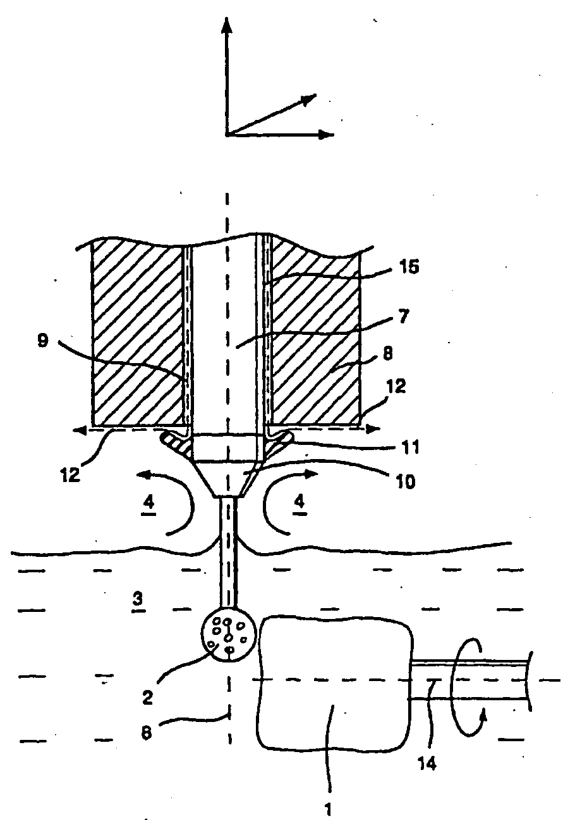
(54) Title: METHOD AND DEVICE FOR THE ABRASIVE PRECISION MACHINING OF A BLANK

(57) Abstract

The present invention concerns a procedure and an arrangement for the abrasive precision machining of a blank (1) made of a material with a high degree of hardness and/or toughness by means of a rotating high speed abrasive tool (2) that has a rotation speed of more than 30,000 revolutions per minute (rpm), where the blank is arranged in a liquid (3) and the machining is carried out under the surface of the liquid. The procedure includes a negative prssure being created in the area (4) of the rotating tool's drive axle above the liquid surface. The arrangement includes a driving device that rotates an abrasive tool (2) where the driving device is able to transfer a number of rotations that exceeds 30,000 rpm, a device for holding the blank (1) that is to be machined, as well as a device for adjusting the relative positions of the blank and the tool to one another for carrying out the machining, during which a liquid (3) is arranged to surround the blank (1) during machining so that the machining takes place under the surface of the liquid, whereby a driving device includes a spindle (7) arranged in a spindle housing (8), a forced air stream (9) is arranged in the area of the end of the spindle that supports the tool (10), and a device to direct the flow of air (11) is arranged at a distance above the liquid surface, plus that the flow-directing device is able to change the direction of the forced air stream to flow in a divergent direction (12) relative to the spindle.



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METHOD AND DEVICE FOR THE ABRASIVE PRECISION MACHINING OF A BLANK

The present invention concerns a procedure and device for the abrasive precision machining of a blank made of a material with a high degree of hardness by means of a rotating high speed abrasive tool that works with a rotation speed of more than 30,000 revolutions per minute (rpm). More specifically, the procedure and device is intended for producing parts for dental restoration or repair bodies for use as fillings, for example.

The problem of machining new materials with a high degree of hardness and/or toughness has limited the use of such materials. For example, ceramic powders or granules, lightweight metals, plastics and composites are often difficult to machine using conventional techniques. Small, elaborate shapes with high demands placed on their outer surface are especially problematic. Machining hard material must often be done by diamond grinding, which is expensive, especially if its efficiency is low. Grinding has often accounted for more than half of the production cost. It has been difficult to produce small series of products made from these materials, which has hindered the development of new products in what is, in fact, promising material. Examples of products include dental fillings, orthopaedic implants and machine parts.

For grinding tools that use hard grinding material such as diamonds and boron nitride, the wear and tear on the grinding tool often accounts for a substantial proportion of the cost of machining. It is often advantageous to use grinding speeds in excess of 10 m/s. Such speeds are difficult to achieve with small tools. Small tools are need for small complex shapes. For example, with a typical rotation speed of 20,000 rpm and a tool with a diameter of 2 mm, the grinding speed will be 0.002 m x 3.14 x 20.000 / 60 s = 2.1 m/s. This gives rise to low milling efficiency and wear of the diamond tool.

If, for example, an air-cushioned high speed spindle with 180,000 rpm is used, the equivalent grinding speed will be 0.002 m x 3.14 x 180,000 / 60 s = 18.8 m/s. The problem has primarily been that the high rotation speed is counter-productive to the effective cooling of the tool. A cushion of air is formed around the tool and this hinders the coolant from cooling the tool efficiently. Diamonds that reach over 500 °C easily carbonise on their surface and thus become blunt, which results in the development of even more heat. The result is normally that the grinding tool becomes dull and that wear and tear becomes significant.

With the help of the invention, such high speed machining has been shown to be very effective. Milling speeds of about 500 mm^3/min in difficult to work ceramics have been achieved with limited wear on the tool (diamond tool).

For machining with high speed spindles, air-cushioned, electrically driven spindles are most suitable. Air cushioning counteracts vibrations compared with conventional ball bearing spindles. With electrical power, one can easily attain sufficient momentum and power so that the spindle speed does not drop off under loading. This phenomenon makes the air-driven (hand-held) devices used by dentists unsuitable for automated tools. A dentist hears by the noise if the speed drops and can then ease the loading straightaway. This is much more difficult to do in a fast working machine tool.

One of the objectives of the present invention is to overcome some of the above mentioned disadvantages and problems of known techniques. This objective is achieved by means of the procedure and device first mentioned above and that possess the special features given in the characteristics of their respective independent claims.

By means of the invention, a technique for the fast and efficient high precision abrasive machining of blanks for the production of dental items is achieved. The blanks can be made of

ceramic powder or granule material, plastics, composites, etc. A blank that can be used with advantage for dental objects is zirconium dioxide.

The procedure for precision abrasive machining according to the invention shows the stage where the blank is arranged in a liquid and where the machining is carried out by the movement of the blank and the tool relative to one another under the surface of the liquid.

To achieve sufficiently great detail and high resolution of the finished machined object, a machine tool with a relatively small diameter, often under 2 mm, is required. Achieving the optimal cutting speed for the tool, means that a very high rotation speed, often over 100,000 rpm is needed. Even 200,000 rpm can be required.

To prevent the liquid that is expected to contribute to the cooling effect being forced out of the tool and thereby the actual location of the machining, a negative pressure can, according to one embodiment of the invention, be achieved in the space above the liquid surface where the tool is immersed in the liquid. The displacement of liquid is essentially due to turbulence formed by the rotation of the tool. It can nevertheless, not be excluded that bubbles are formed in the hot area around the machining and that these contribute to the displacement. The suction effect of the said negative pressure counteracts this displacement and causes the liquid to be drawn in against the tool.

According to the invention, the negative pressure can be achieved in the area of the tool's rotating drive shaft above the surface of the liquid by a stream of air being conducted at a distance above the liquid surface to flow in divergent streams in a direction essentially coinciding with a plane at right angles to the axis of rotation of the tool, so that a negative pressure in the area surrounding the tool's drive axle and between the surface of the liquid and the flow of air is achieved.

The arrangement according to the present invention includes a driving device that rotates an abrasive tool where the driving device is able to transfer a number of rotations that exceeds 30,000 rpm, a device for supporting the blank that is to be machined, as well as a device for adjusting the relative positions of the blank and the tool to one another in order to carry out the machining. The arrangement also includes a liquid arranged to surround the blank during machining so that the machining takes place under the surface of the liquid.

The driving device can advantageously include a spindle arranged in a spindle housing and a forced air stream can be arranged in the area of the end of the spindle that supports the tool. A device to direct the flow of air can be arranged at a distance above the liquid surface for the purpose of changing the direction of the forced air stream to flow in a divergent direction relative to the spindle. If the divergent air flow moves essentially parallel with a plane that constitutes the plane at right angles to the axis of rotation of the tool, and if the flow of air only passes the said area, a negative suction pressure will be formed in the area and will cause the liquid to be drawn in against the tool.

A chuck can with advantage be arranged on the spindle for the quick and easy release of the tool, and the device that directs the flow can be arranged on the chuck.

The flow direction device can include a ring-shaped collar arranged round the chuck and the collar's cross-section can have a wing-shaped flange for regulating the air flow.

The device for supporting the blank, the holding device, includes at least one pivoting axis, around which the holding device is able to pivot the blank. It can be advantageous if the holding device also includes a housing that can accommodate several blanks, so that following completion of machining, the holding device can set down the finished machined item and pick up a new blank for machining.

The spindle housing is arranged to be linearly moveable in two or three directions. The spindle housing can also be pivoted about one or more axes. It is preferable if the spindle housing is manoeuvred and regulated by numerical information from a calculation and memory unit - a computer. The holding device can also be manoeuvred and regulated by the same computer as part of the device for regulating and manoeuvring the relative positions of the blank and the tool to one another.

It is advantageous if the spindle is supported in relation to the spindle housing by means of a cushion of air formed by what is essentially a tube-shaped flow of air created in a clearance between the spindle housing and the spindle. A gliding surface of air is formed by the continuous provision of an air flow during operation. By directing the flow of air through the spindle housing towards the end of the spindle carrying the tool, the said flow of forced air is obtained at the same time.

This flow of forced air can also naturally be achieved through the provision of air via channels in the spindle or spindle housing or by other air lines opening into the area.

In an alternative embodiment, the forced air flow can also be achieved by, for example, a propeller, a blade or a fan-like construction, when the air lines serve as intakes for the forced air flow generated by the propeller that drives the divergent air flow following to the directional device.

The liquid can be water with or without lubricants and/or additives that lower the surface tension, an oil or another suitable liquid with similar characteristics.

Further features and advantages of the invention will become evident from the following detailed description of one preferred embodiment of the invention, which constitutes one example and as such does not limit the extent of protection for the invention. To clarify understanding, the

text contains references to the enclosed drawing of a figure. The **figure** shows a schematic and partly stripped-away arrangement of one preferred embodiment of the present invention.

The arrangement for producing a dental repair body, in this case a filling in a drilled hole in a tooth, includes a driving device that can rotate an abrasive tool 2 with a speed of rotation of approximately 180,000 rpm. The driving device includes an electric motor (not shown) for driving a spindle 7.

In addition, the arrangement includes a device for supporting the blank 1 that is to be machined to fit into the hole in the tooth. This supporting device can pivot the blank around a pivoting axis 14 to facilitate the machining and also has a manoeuvrable clasp and transfer device (not shown in the figure) that makes possible the automatic exchange of blanks. A housing with blanks is also arranged within reach of the clasp and transfer device, which facilitates the exchange of blanks.

A device is also arranged for the regulation and manoeuvring of the blank's 1 and the tool's 2 relative positions to one another for carrying out the precision machining, and a liquid 3 is arranged to cover the blank during machining. The liquid, in this case water, is in a vessel with sufficient depth and access to allow the machining.

In addition, the spindle is air-cushioned in relation to the spindle housing by a pressurised air flow 15 that, during operation, is arranged to flow between the spindle and the spindle housing in a downwards direction from the top of the figure. A chuck 10 is arranged at the lower free end of the spindle to facilitate the easy exchange of tools. A device to direct the air flow is arranged around the chuck in the shape of a circular flange 11 at a distance above the surface of the liquid. The flange 11 can change the direction of the forced flow of air 9 to what is a divergent flow 12 in relation to the spindle. If another type of cushioning that hinders the cushioning air flow 15

from also constituting the forced air flow 9 is used, special supply lines can be arranged to open adjacent to the device 11 that changes the direction of flow. In the example shown, the flange 11 has a winged shape to regulate the flow of air.

The spindle housing 8 can be manoeuvred in three directions, x, y and z, which, together with the manoeuvring of the blank around axis 14, is sufficient to carry out the machining.

Claims

1. Procedure for the abrasive precision machining of a blank (1) made of a material with a high degree of hardness and/or toughness by means of a rotating high speed abrasive tool (2) that has a rotation speed of more than 30,000 revolutions per minute (rpm), where the blank is arranged in a liquid (3) and the machining is carried out under the surface of the liquid, characterised in that a negative pressure is achieved in the area (4) of the rotating tool's drive axle above the liquid surface.

2. Procedure according to claim 1 characterised in that an air flow is conducted above the surface of the liquid in a divergent stream that essentially coincides with the plane at right angles to the axis of rotation (6) by which a negative suction pressure is formed in the area (4) around the tool's drive axle and between the surface of the liquid and the stream of air.

3. Procedure according to claim 1 to 2 characterised in that a mathematical description of the result intended to be produced by the machining is supplied to a calculation unit (computer), that a mathematical description of the blank is supplied to the computer, and that the instructions for machining are carried out by a device holding the blank and a device holding the tool.

4. Arrangement for the abrasive precision machining of a blank (1) made of a material with a high degree of hardness and/or toughness, including a driving device rotating an abrasive tool (2) where the driving device is able to transfer a number of rotations that exceeds 30,000 rpm, a device for holding the blank (1) that is to be machined, as well as a device for adjusting the relative positions of the blank and the tool to one another in order to carry out the machining, whereby liquid (3) is arranged to surround the blank (1) during machining so that the machining

takes place under the surface of the liquid, characterised in that the driving device includes a spindle (7) arranged in a spindle housing (8), that a forced air flow (9) is arranged in the area of the end of the spindle that supports the tool (10), that a device to direct the flow of air (11) is arranged at a distance above the liquid surface, and that the flow-directing device is able to change the direction of the forced air stream to flow in a divergent direction (12) relative to the spindle.

5. Arrangement according to claim 4 characterised in that the device to direct the flow of air (11) produces a divergent air stream (12) that flows essentially parallel with a plane that constitutes the plane at right angles to the axis of rotation of the tool (6).

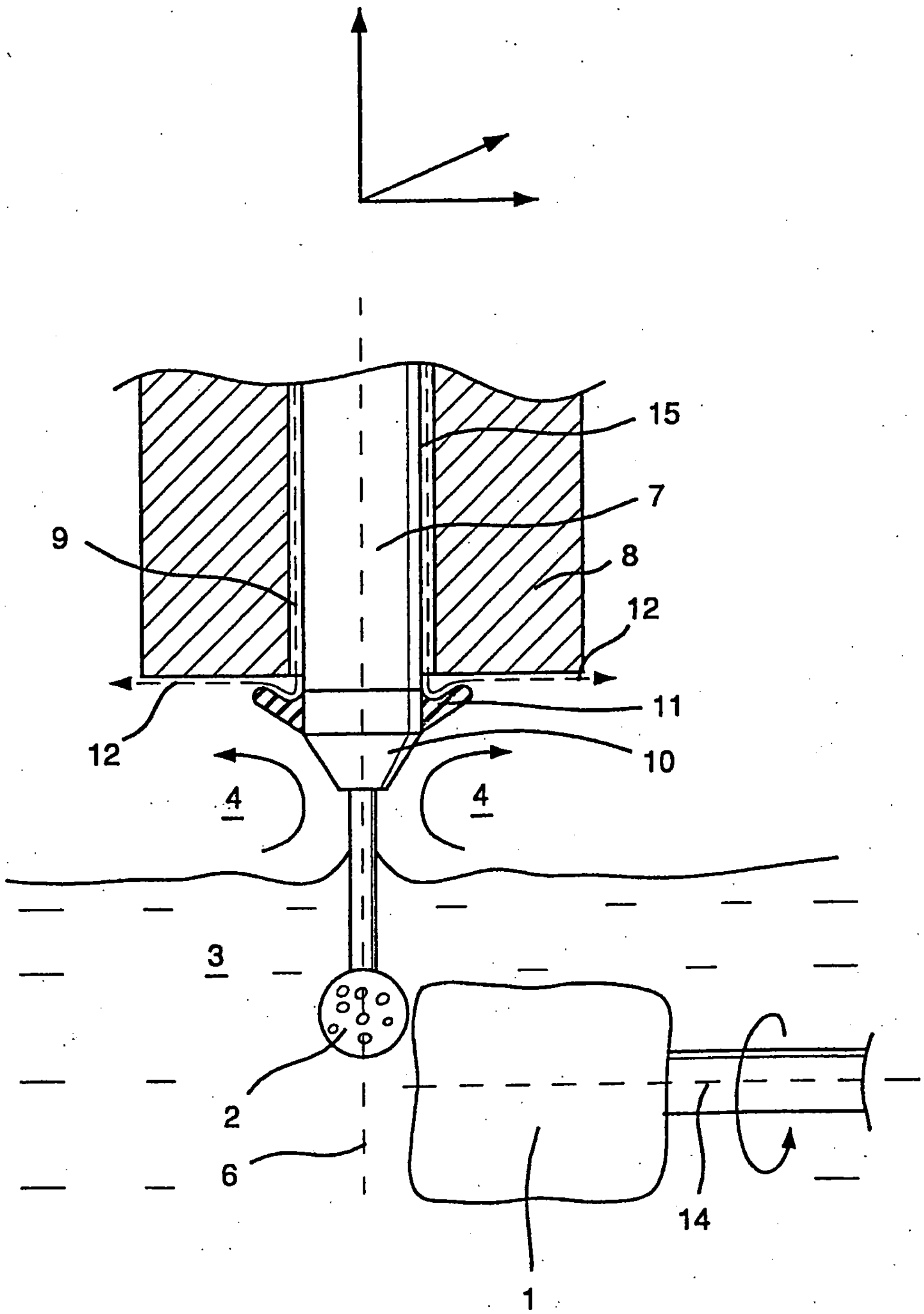
6. Arrangement according to any of claims 4 or 5 characterised in that a chuck (10) is arranged on the spindle for the connection and disconnection of the tool (2) and that the device that directs the air flow (11) is arranged in connection with the chuck.

7. Arrangement according to claim 6 characterised in that the flow direction device includes a ring-shaped collar arranged round the chuck (10) and the collar's cross-section has a wing-shaped flange for regulating the air flow.

8. Arrangement according to any of claims 4 to 7 characterised in that the spindle (7) is held in relation to the spindle housing (8) by means of an air cushion that is formed by an essentially tube-shaped flow of air (15) created in a clearance between the spindle housing (8) and the spindle (7), and that by directing the flow of air through the spindle housing towards the end of the spindle carrying the tool (10), the said flow of forced air (9) is achieved.

9. Arrangement according to any of claims 4 to 8 characterised in that the device for holding the blank includes at least one pivoting axle (14) around which the holding device is able to turn the blank, that the holding device includes a housing that can accommodate several

blanks (1) so that following completion of machining, the holding device is able to pick up a new blank for machining, that the holding device is manoeuvred and regulated by numerical information from a computer, that the spindle housing (8) is arranged to be moveable in at least two and preferably three directions, and that the device for regulating the relative positions of the blank and the tool to one another includes a computer that includes a calculating and a memory storage unit for handling numerical information such as machining instructions.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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/00276

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: B24B 55/02, B23Q 11/10, B28D 7/02, G05B 19/18
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: B24B, B23Q, B28D, G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	WO 9534802 A1 (NORSK HYDRO A.S.), 21 December 1995 (21.12.95), figure 1, claim 1 --	9
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A	DE 3115959 A1 (THYSSEN INDUSTRIE AG), 4 November 1982 (04.11.82), figure 6 --	1,4

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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